Properties of LED – considering museum lighting

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Properties of LED
– considering museum lighting

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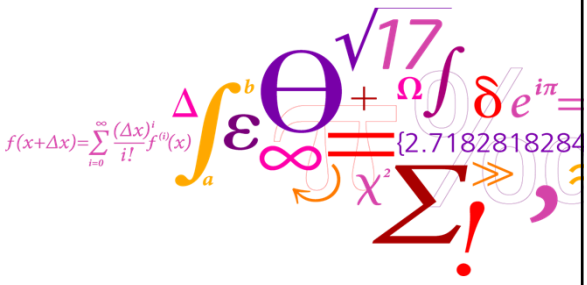

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Contents

Solid State Lighting (SSL) i.e. LED based lighting is a "new" lighting technology that may offer many advantages for museum lighting.

- **Light - Ultraviolet / Visible / Infrared**
- **Energy efficiency of LED packages and SSL products**
- **Light quality in color temperature and color rendering**
- **Maintenance of luminous flux and color**
- **Test and characterisation**

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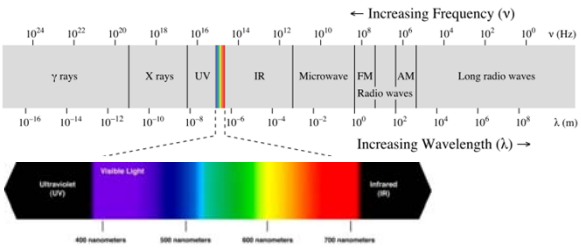
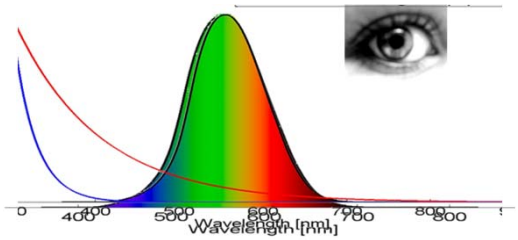
Spectral properties of light

Light (visible light) is electromagnetic radiation in the visible range



In museum lighting we need to consider also UV and IR light

Photometry specifies the perceived brightness of light taking the human eye sensitivity into consideration (standard observer)



Radiometry specifies the radiant power in Watts (in a specific spectral range)

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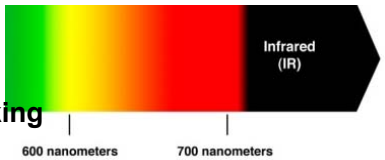
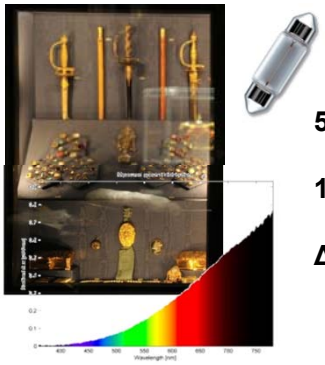
IR radiation

Infrared radiation, wavelenghts > 780 nm
will cause heat and related humidity variations
May cause surface hardening, discolouration and cracking



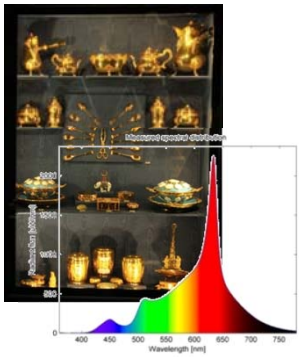
Rosenborg treasury, display case illumination



5 W bulbs

130-150 W

ΔT : 9-12 deg.



Custom LED

25-32 W

ΔT : < 1 deg.

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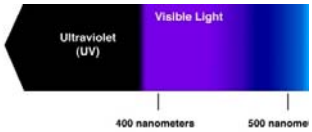
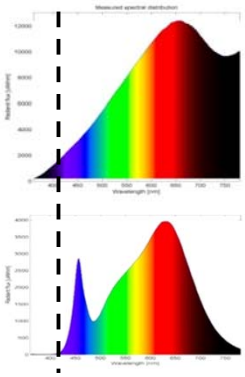
UV radiation

useful to state the amount of UV per visible flux produced, in terms of microwatts per lumen (µW/lm)





Light Source	UV Content (µW/lm)
Daylight	400 – 1500
Tungsten Incandescent	70 – 80
Tungsten halogen (incl. UV stop lamps)	40 – 170
Fluorescent	30 – 100
Metal halide	160 – 700
LEDs	< 5

CIE 157:2004

But UV LEDs and UV based white LEDs

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LED packages, flux and efficiencies

LED packages

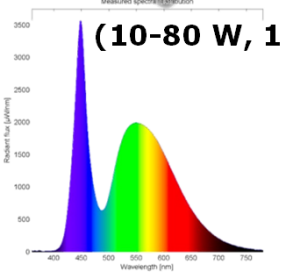
3 mm

(~ 1-5 W, ~1000 lm)

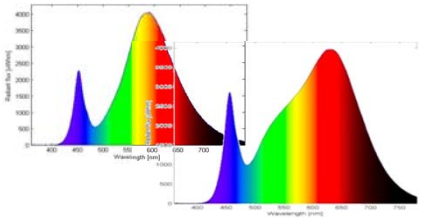
(10-80 W, 1500-6000 lm)

Color temperature

2700 - 3500 K **> 5000 K**



Efficiency:
123 lm @ 350 mA ~ 117 lm/W



160 lm @ 350 mA ~ 152 lm/W (@ 25 °C)
139 lm @ 350 mA ~ 132 lm/W (@ 85 °C)

Lab results 2014: 303 lm/W

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Status, SSL products

SSL products are based on LED packages including optics, heat sinks and driver electronics
Retrofit products

LED lamps (cap)

50-100 lm/W

LED luminaires

~ 90-110 lm/W

LED modules (no cap)

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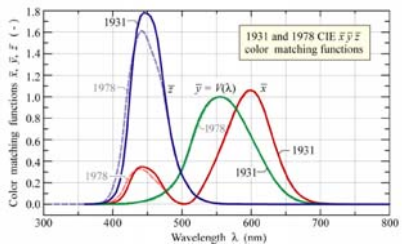
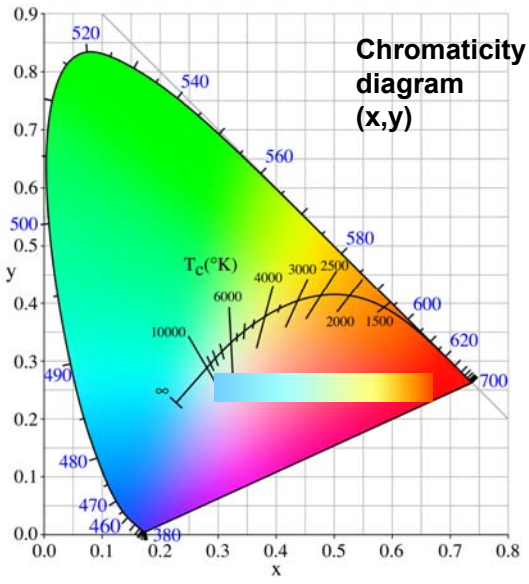
Colorimetry

Is used to describe the color of perceived light



Color sensitivity of the standard observer



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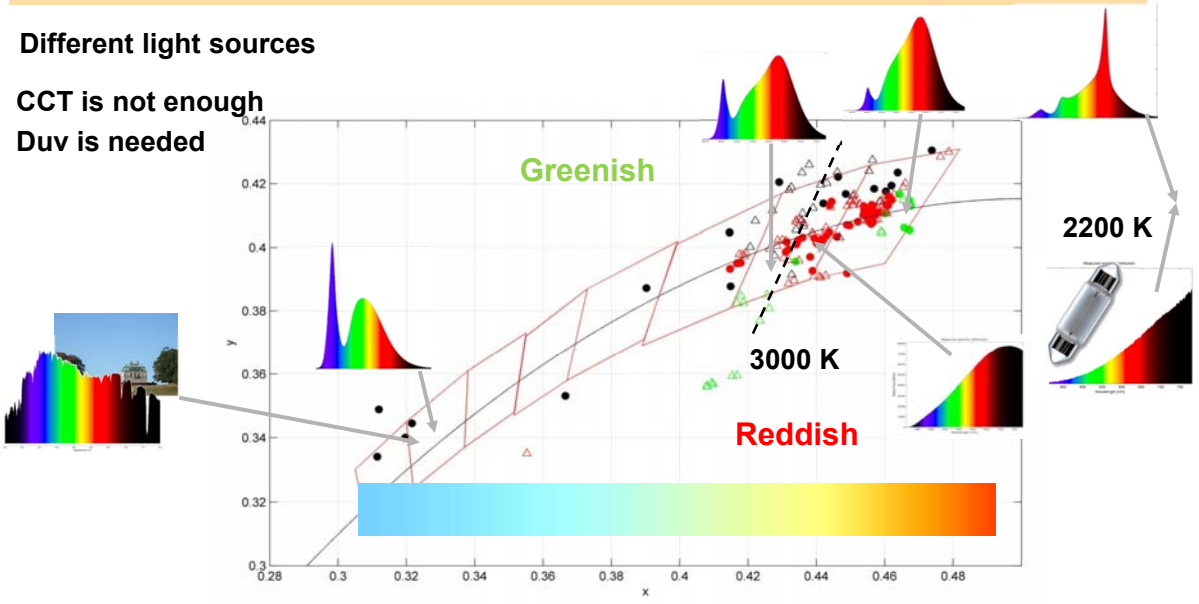
Color temperature

Different light sources

CCT is not enough
Duv is needed



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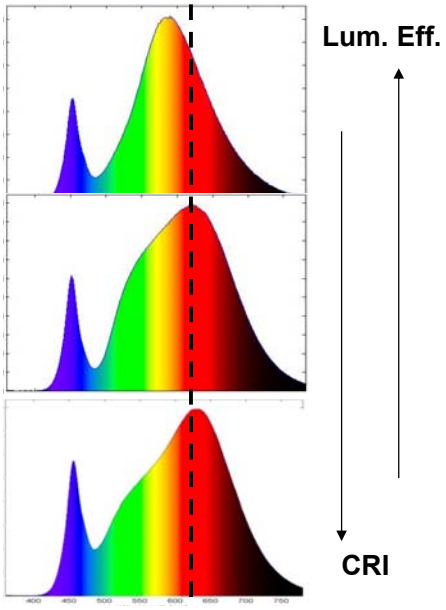
Color rendering

Different spectral power distributions has the same CCT~3000K,
but very different color rendering:

i	Appearance under daylight	Swatch	CRI i	CRI = 68.6 CRI i	84.7 CRI i	95.4 CRI i
1	Light greyish red		63.2	84.8	98.4
2	Dark greyish yellow		80.3	88.3	97.3
3	Strong yellow green		93.2	88.9	97.0
4	Moderate yellowish green		60.1	84.1	94.6
5	Light bluish green		61.7	82.2	98.0
6	Light blue		70.4	81.9	94.2
7	Light violet		77.3	90.4	92.5
8	Light reddish purple		41.9	76.8	91.3
9	Strong red		-35.5	44.4	85.0
10	Strong yellow		54.4	70.3	96.6
11	Strong green		50.1	80.6	93.8
12	Strong blue		41.6	58.8	82.4
13	Light yellowish pink (skin)		66.2	85.0	98.4
14	Moderate olive green (leaf)		96.2	92.8	98.3



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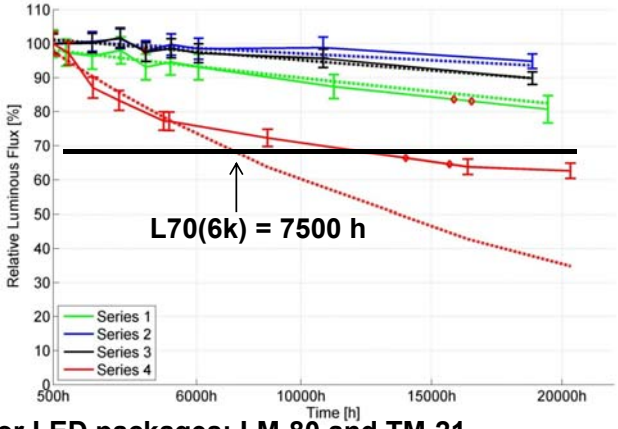
Luminous flux maintenance

LEDs doesn't fail suddenly, but degrades slowly –
Long term measurements of lumen maintenace of 48 retrofit LED lamps over 20.000 h



Established IES standard for LED packages: LM-80 and TM-21
New IES standards for LED lamps: LM-84-14 and TM-28-14
Need for accelerated test methods, with on/off cycling

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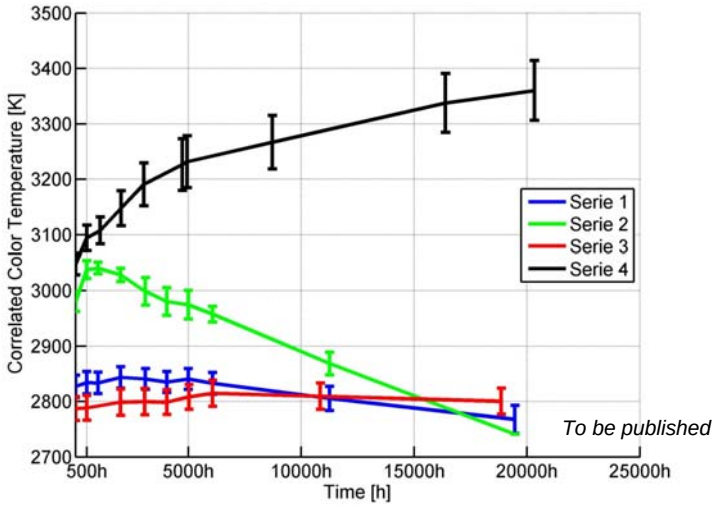
Color maintenance

Correlated color temperature as a function of time:



To be published

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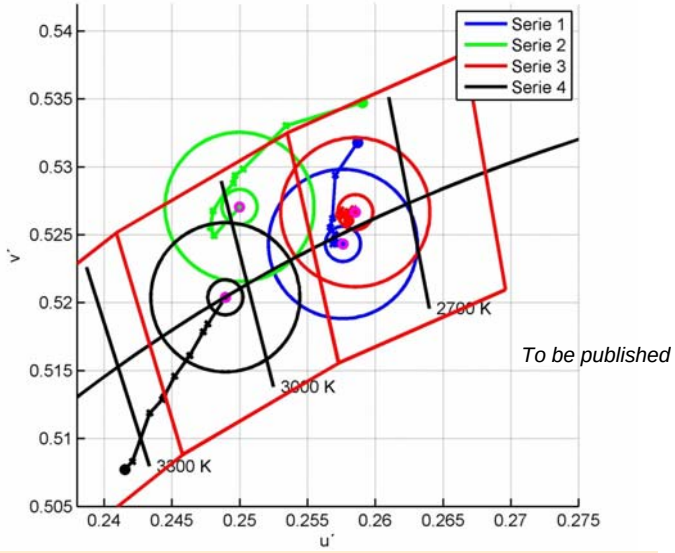
Color maintenance

Color change even if CCT is constant, chromaticity coordinates as a function of time:



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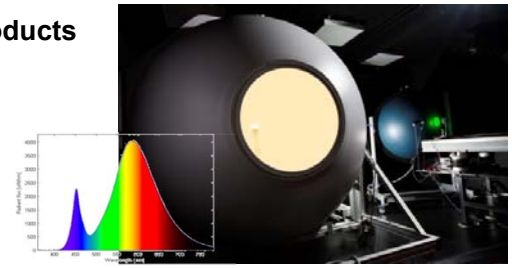
Test and characterisation

There is a need for characterisation of SSL products

- **Spectral power distribution, UV,Vis (and IR)**
- **Luminous flux**
- **Efficiency**
- **Correlated Color temperature, Duv**
- **Color rendering index**
- **Luminous flux and color maintenance**
- **Relative damage factor**

- **Intensity distribution and color**

- **Illuminace, irradiance**
- **Double monochromator**
- **Handheld spectrometer**



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Test and characterisation

Draft international test standard has been published:

CIE DIS 025/E:2014 Test Method for LED Lamps, LED Luminaires and LED Modules

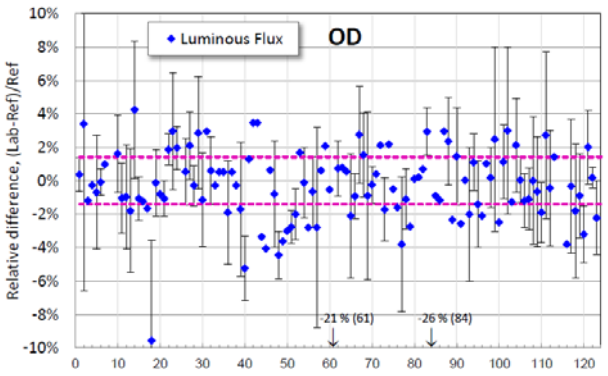
EN 13032 Lighting Applications - Measurement and presentation of photometric data of lamps and luminaires - Part 4: LED lamps, modules and luminaires

tested through an interlaboratory comparison IC2013 by the

IEA SSL Annex
2010-2014 + 2014-2019

Efficient Electrical End-Use Equipment
International Energy Agency

110 laboratories



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Conclusion

Solid State Lighting (SSL) i.e. LED based lighting is a "new" lighting technology that offers

- **Limited UV and IR radiation**
- **High energy efficiency**
- **High light quality in color temperature and color rendering**
- **Long life time**
- **Color tunability**
- **Dimming, sensor based system to reduce exposure**
- **Need to test and characterise**

Thank you to all my coworkers at the LED team at DTU Fotonik,
and for your kind attention

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